Niche breadth and overlap among two sympatric wild ungulates and domestic cattle in Shuklaphanta National Park, Nepal

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Abstract

Understanding niche overlap with other wild species and domestic cattle is useful to conserve and manage the wildlife in their natural habitat. We assessed habitat niche breadth and overlap among the two sympatric wild ungulates: spotted deer (Axis axis) and swamp deer (Cervus duvaucelii) and, indigenous intermediate ruminants, and domestic cattle in Shuklaphanta National Park, Nepal during the dry season. Our objective was to explore the interspecific competition by studying the habitat use by these species. The assumption was made that the presence of pellets is a proof for habitat used by species. Grid based surveys with total 96 sample plots each of size 20 m * 20 m in 6 sample grids (2 * 2 km2) with 24 sub-grids (500 * 500 m2) were used for locating pellets group. Levin's niche breadth and Morisita's overlap index were calculated to determine the niche breadth, and the habitat overlap respectively. The Levin's measure of niche breadth suggested that spotted deer had the highest adaptability with an index value of 0.94 followed by domestic cattle 0.50, and swamp deer 0.33 in our study area. Thus, it was concluded that spotted deer is a habitat generalist whereas swamp deer are specialists and mostly preferred grasslands after a fire. Also, there was high habitat overlap index value of 0.83 between domestic cattle and spotted deer whereas the swamp deer and the spotted deer showed moderate habitat overlap of 0.57. The swamp deer had low habitat overlap as well as spatial overlap with domestic cattle. Grassland management should be carried out for the benefit of ungulate species as the study showed the preference of swamp deer on grassland after a fire. Similar studies should be conducted including seasons and places prior to implementing appropriate habitat management activities intended to reduce interspecific competition for co-existence.

1. INTRODUCTION

Differential resource use allows for diverse species to specialize in ecological niches and thus coexist in a particular area and this theory has been stimulated one of the most fertile fields in ecology (Chase and Leibold, 2003). The requirement-based concept of the ecological niche (Grinnell, 1917; Hutchinson, 1957) defines it as a function that links the fitness of individuals to their environment. Whenever several species co-exist, biotic interactions (like competition, predation, parasitism, mutualism) affect their fitness and behavior and may drastically affect their niches (Pearson and Dawson, 2003).

Morphologically and phylogenetically, similar sympatric species are expected to have niche overlap and competitive interactions under conditions of limited resources (Schoener, 1974; Putman, 1996). Hence, potentially competing sympatric species are expected to develop niche differentiation to avoid or decrease competition (Pianka, 1974; Schoener, 1974; Putman, 1996). The spatial aspect of niche (habitat) is the most commonly partitioned resource followed by food (Schoener, 1974, 1983; Toft, 1985). Habitat selection and the niche theory explains that similar species with similar niches should be allopatric or possess some of

their behavioral aspects that separate them spatially or temporally within the same range. The coexistence of competitive species co-occurs in the same habitat as a result of the resource partitioning (Hardin, 1960). Niche breadth can be measured by observing the distribution of individual organism within a set of resource states. Some plants and animals are more specialized than others and measure of niche breadth attempt to measure this quantitatively.

Swamp deer (*Cervus duvaucelii*) has been enlisted as the "vulnerable" in the red list of International Union for Conservation of Nature (IUCN) (Duckworth et al., 2015b) and is listed on Appendix I of Convention on international trade in endangered species of wild fauna and flora (CITES) (CITES, 2019). This deer was extirpated from Chitwan National Park of Nepal during the 1960s, possibly due to a combination of factors (e.g. poaching, disease and habitat loss) (Duckworth et al., 2015b). Swamp deer is one of 27 mammal species strictly protected by the National Parks and Wildlife Conservation Act 2029 (1973) of Nepal. Swamp deer mortality is largely by predation, flooding (for *R. d. duvaucelii* and *R. d. ranjitsinhii*) and poaching. Tiger (*Panthera tigris*) is a major predator of this deer and there are few reports of kills by leopard (*P. pardus*) and dhole (*Cuon alpinus*) (Qureshi et al., 2004). Swamp deer is predominantly a grazer (Qureshi et al., 2004), but at least *R. d. duvaucelii* is known to feed occasionally on aquatic plants, and aquatic plants contribute significantly to the diet of *R. d. ranjitsinhi* during the monsoon and winter (Qureshi et al., 1994).

Spotted deer (*Axis axis*) has been enlisted as the "least concern" in the red list of International Union for Conservation of Nature (IUCN) (Duckworth et al., 2015a). Spotted deer is a plastic species capable of considerable adaptive response. This characteristic is well reflected through its wide-ranging distribution in India and even where it is an exotic (Dave, 2008). Also, most of the natural ranges of spotted deer are shared with livestock (Dave, 2008).

In Nepal, out of four localities reported by Schaller (1967), only two of them hold the species at present. Thus, there are ongoing plans in Nepal to translocate some of the deer from Suklaphanta National Park (SNP) to boost the smaller population of Bardia National Park (BNP) (Duckworth et al., 2015b). The Department of National Parks and Wildlife Conservation is also looking at the feasibility of re-introducing the species to Chitwan National Park (CNP) (Duckworth et al., 2015b). At the same time it is essential to know about the competitive behavior of this species at its natural habitat. Intensive grazing by large number of cattle have created severe condition in SNP (Bhattarai, 2012). Domestic cattle grazing and other disruptions may affect the nutritional stability of wild animals because they expend additional energy moving away from the disruptions and may be forced to forage in poor habitats instead of high-quality patches, and consequently may be competitively excluded from better habitats (Schaller, 1977). Quantitative studies on these aspects are required in order to understand the relationships between domestic cattle and herbivores, which are crucial to understanding the major factors limiting wild ungulates densities and formulation of a meaningful conservation plan for the region and species.

Thus, this study tried to quantify the potential competition based on overlap in two dimensions, habitat and space, between the indigenous and domestic species. We focused on swamp deer and spotted deer, living sympatrically in SNP along with the domestic cattle. This study assessed the vulnerability of species by determining the niche breadth regarding habitat use by the species, assessed the habitat overlap among wild and domestic herbivores and explored whether the potential exists for direct interspecific competition.

2. MATERIAL AND METHODS

2.1. Study area

This study was conducted in SNP of Nepal that lies in the far western part of Nepal at 28° 42' 29"N- 29° 03' 27"N; 80° 03' 08"E- 80°25' 53"E and covers an area of 305 km^2 with additional buffer zone area of 243 km^2 (SNP, 2017) (**Figure 1**). Abandoned agriculture land occupies 7.87%, forest 65.02%, grassland 16.10%, shrub land 3.76% and water bodies 7.25% (NTNC, 2017). National highway passes through its upper tip breaking link with Mahabharat range. SNP possesses the largest patch of grassland in Nepal covering an area of 54 km^2, called Shuklaphanta grassland, which is important for globally threatened species. Most of the park area is covered with *Shorea robusta*forest. Barking deer (*Muntiacus muntjak*), blue bull (*Boselaphus*

tragocamelus), hog deer (*Heylaphus porcinus*), rhesus macaque (*Macaca mulata*) spotted deer, swamp deer, wild Asian elephant (*Elephas maximus*), wild pig (*Sus scrofa*), and are the major wild prey species of tiger in SNP (DNPWC, 2016; NTNC, 2017; Sharma et al., 2020). SNP hold most of the remaining swamp deer population including Lagga Bagga, Krishnapur and Dudhwa National Park of India (Duckworth et al., 2015b). Domestic cattle grazing along with intensifying human pressure is one of the main threats to the Shuklaphanta National Park (Bhattarai, 2012).

2.2. Field methods and analysis

Grid based surveys with total 96 sample plots each of size 20 m * 20 m in 6 sample grids (2 * 2 km^2) with 24 sub-grids (500 * 500 m^2) were used for locating pellets group. Preliminary field survey and discussions with the park staffs were done prior to field visit and the grids were selected based on the factor like, they represent all habitat types, the presence of species under consideration, accessibility etc. Direct field observation and pellet count method were used for this research. Pellet count method can easily determine the areas used intensively by animals (Julander, 1958). Pellets of the different species were distinguished from each other by their size and shape following Rivero et al. (2005) and with the help of local field assistant familiar with the wildlife species of the study area. During the observations, we recorded the habitat types where we located the pellets. Levin's measure of niche breadth was calculated for all species under study based on equation given below (Krebs, 1999).

$$B = \frac{1}{\sum \mathrm{Pi}^2}$$

B' = $\frac{B-1}{n-1}$

Where,

B = Levin's measure of niche breadth

B '=Standardized niche breadth

p_{i}= Proportion of individuals found in or using resource state i

n= number of possible resource state

The percentage of cover overlap between species pair or spatial overlap was determined by knowing the number of plots shared by species in the sample grids. The proportion of different habitat types used by different species was determined based on field study results. Then Morisita's index was used to determine the resource overlap between the pair of species as described in (Krebs, 1999). The index values range from 0 to 1. Zero represents no overlap whereas 1 represents maximum overlap. Three levels of overlap were defined as done by Jung & Czetwertynski (2013) as high overlap ([?]0.80), moderate overlap (0.40-0.80) and low overlap (<0.40).

$$c = \frac{2\sum_i^n p_{\mathrm{ij}} \, . \, p_{\mathrm{ik}}}{\sum_i^n p_{\mathrm{ij}}^{\frac{(n_{\mathrm{ij}}-1)}{(N_j-1)}} + \sum_i^n p_{\mathrm{ik}}^{\frac{(n_{\mathrm{ij}}-1)}{(N_j-1)}}}$$

$$\sum_{i=1}^{n} n_{\mathrm{ij}} = N_{\mathrm{j}} \; ; \sum_{i=1}^{n} n_{\mathrm{ik}} = N_k$$

where,

c = Morisita's index of niche overlap between species j and k

p_{ij}= Proportion resource i is of the total resources used by species j,

p_{ik} = Proportion resource i is of the total resources used by species k,

n_{ij}, = Number of individuals of species j that use resource category I,

n_{ik} = Number of individuals of species k that use resource category I,

N_j, N_k = Total number of individuals of each species in sample.

3. RESULTS

Seven habitat types were found in SNP including forest and grasslands. They are closed *Shorea* forest, open *Shorea* forest or*Shorea* savana, riverine forest, short grassland, tall grassland, grassland after fire and floodplain grassland. From the fecal counts from the grid-based sampling during dry season, the Levin's measure of niche breadth or adaptability showed that spotted deer had the highest adaptability with index value of **0.94** followed by domestic cattle **0.50** , and swamp deer **0.33** in SNP (Table 1).

The co-occurrence of swamp deer and spotted deer was observed in**69.5%** of plots in which presence of swamp deer was recorded. The co-occurrence of domestic cattle and spotted deer was detected in**28.9%** of plots in which presence of spotted deer was recorded but the co-occurrence of domestic cattle and swamp deer was negligible.

During the dry season domestic cattle have high Morisita's index of overlap **0.83** with spotted deer. The spotted deer have moderate overlap index value **0.57** with swamp deer whereas there is low overlap index value of swamp deer with domestic cattle **0.23**(Table 2).

Interaction of domestic cattle with wild species is very high in Sal forest while there is no any interaction in tall grassland and grassland after fire (Figure 2).

4. DISCUSSION

The SNP is a globally recognized area by supporting the word's largest herd of swamp deer population (Poudel, 2007). However, at present, this species is restricted only in SNP and BNP of Nepal, which has always been at the risk of extinction due to the possible disturbances. Realizing this fact, a study was conducted to find out some suitable areas in CNP of Nepal for translocation them to establish another sub-population (Ghimire et al., 2019), but this might take longer period from translocation programs to establishment of viable sub-populations. Similarly, grazing of domestic cattle is one of the severe problems in the park area that increases competitions with the wild herbivores (Bhattarai, 2012). Thus, we studied about the situation of interspecific competition with spotted deer and domestic herbivores in the study area. The main presumption of this work is that habitat is a main element of the ecological niche (Schoener, 1989)(Chase and Leibold, 2003).

The swamp deer were present in the grasslands predominantly. Wegge et al. (2006) also reported more late successional grasses (*Narangaand* *Themeda* spp.) and short grasses (mainly *Imperata cylindrica*) in the diet of swamp deer. A total of 55% presence of swamp deer was recorded in the grasslands after fire where they get new sprouts of grass as well as the ash, a source of minerals. They adapted to all types of grassland. According to Moe and Wegge (1997), cut-and-burned treatment gave the increase in forage quality as well as the deer density, as the deer preferred the burned plots. Similarly, a study conducted in Uttarakhand, India has also reported grasses and herbs as the major diet of swamp deer (Tewari and Rawat, 2013). In contrast, the spotted deer did not show many differences in the use of different habitat types. Spotted deer eat both grass and browse, with the former providing the bulk of their diet at all seasons (Kushwaha, 2016). It is predominantly a grazer but consumes more fallen leaves, flowers and fruits in winter/dry season (Sankar, 1994; Sankar and Acharya, 2004; Raman, 2013). It co-existed with the domestic species and was prevalent even near human disturbance areas. The density of spotted deer was 79 km^{-2} in SNP followed by swamp deer 30 km^{-2} and hog deer 21.6 km^{-2} (Karki et al., 2015). They were found uniformly distributed in forests and grasslands. Spotted deer avoided the areas with dense canopy cover confirming their preference for the open forests (Pokharel and Storch, 2016). The dietary overlap of deer and cattle was highest in winter and the competitive interactions occurred in the winter (Jenks et al., 1996). During summer, spotted deer segregated from others from short grasslands and predators' presence, mixed forest and human disturbances (Bhattarai,

2019). It was mostly recorded in the ecotones such as forest and grassland border (Schaller, 1967; Eisenberg, 1981; Bagchi, 2001). Mixed herds of spotted deer and swamp deer are common on Suklaphanta and Bardia National Parks (Kushwaha, 2016).

These both deer showed the habitat partitioning during the dry season. The spotted segregated from the short grassland and created the suitable environment for the swamp deer. Habitat partitioning is one of the most standard ecological mechanisms to lessen niche overlap and circumvent competition among coexisting species (Rosenzweig, 1981; Traba et al., 2015). Similarly, the spotted deer creates suitable environment to swamp deer consuming the fallen leaves flowers although it is a grazer. The distribution of domestic species shows that the potential for interaction between the wild and domestic species exists more in the*Shorea* forest, floodplain grassland and in the short grasslands. But the distribution of the domestic cattle were not fund so significant in riverine forest, tall grassland and grassland after fire. However, the presence of domestic cattle was observed more near the boundary of the park. Based on the information received from park staffs and filed visit, some of the efforts made by park people to minimize the problem of domestic cattle grazing are mesh wire fencing, electric fencing, intensive patrolling, community awareness etc. Moreover, various habitat management operations are done in few areas to reduce the effect of niche and habitat overlap artificial grass cutting with tractors, waterholes and solar water pumps, controlled fire etc. Likewise, grazing of domestic cattle should be controlled and the plant species utilized by wild ungulates should be protected and increased to minimize the existing competitions. However, detail studies regarding diet composition of these competing species in all seasons and other places are suggested to get clear understanding and information prior to implementing the management activities in the study area.

5. CONCLUSIONS

The swamp deer is dependent on grasslands, especially the grasslands after fire for the new sprouts to meet the food requirements. The habitat of domestic cattle overlapped with wild species mostly in the*Shorea* forest and floodplain grasslands and showed high potential for competition with spotted deer. Spotted deer and swamp deer showed space partitioning though they have moderate habitat overlap which is helpful to minimize the competition between the species having similar feeding habit. Fire on the grasslands is beneficial for the ungulate species. Habitat management focusing the grassland management would be beneficial to conserve the threatened species like swamp deer. More studies are required on the field level before implementing the appropriate management activities to minimize interspecific completion.

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CONFLICT OF INTEREST

None declared.

DATA AVAILABILITY STATEMENT

Data will be available on Dryad.

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Table 1: Niche breadth

Habitat types	Number of plots in which species signs occurred	Number of plots in which species s
	Spotted deer	Swamp deer
Closed Shorea forest	11	0
Open Shorea forest	13	1
Riverine forest	14	1
Short grassland	10	3
Tall grassland	13	4
Grassland after fire	8	12
Grassland in floodplains	7	2
Total	76	23
Levin's Niche Breadth	6.65	3.02
Standardized Levin's Niche breadth	0.94	0.33

Table 2: Morisita's habitat overlap index

Species	Spotted deer	Swamp deer	Domestic cattle
Spotted deer	1	0.57	**0.83**
Swamp deer	0.57	1	0.23
Domestic	**0.83**	0.23	1

Figure 1: Study area

Figure 2: Interaction of domestic cattle with wild species in different habitat types